Chapter

Sewan Grass: A Potential Forage Grass in Arid Environments

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Abstract

Sewan grass (*Lasiurus scindicus*), a popular pastoral species, is getting some much-needed attention as mechanization, modernity in agriculture, and illicit grazing pose severe risks to biodiversity conservation in arid and semi-arid areas. It is found mainly in wastelands, dunes, hammocks, and sandy plains but less popular for cultivation in farmer's fields. Sewan grass has many features like good nutritional value, soil binder, tolerance to high temperature, high digestibility and palatability, and prolonged drought conditions contributed greatly towards its success as a potential forage species in arid environments. It contains significant quantities of crude fibres, lignin, minerals and crude protein, and varies in the proportion of their tissue that can be digested by ruminants. Most research focuses on the species as a forage plant and agronomical practices and is largely published in agricultural and grey literature. Meanwhile, there is a lack of information about breeding strategies and seed production technologies. Therefore, here we present a comprehensive review about agronomic management, breeding, and seed production strategies systematically that will aid in the management of sewan grass now and into the future.

Keywords: Arid environments, Breeding methodologies, Diversification, Nutritional quality, Thar Desert

1. Introduction

Indian hot arid zone covers an area of 32 million ha called 'Thar Desert'. 85 percent of the hot Desert lies in India and the rest of the 15 percent in Pakistan. It represents the most inhospitable arid zone of the world spreading mostly in the states of Rajasthan, Gujarat, Punjab, Haryana, Karnataka, and Andhra Pradesh in India. About 91 percent of the Indian desert falls in Rajasthan covering about 61 percent geographical area of the state. The Aravali hills intersect Rajasthan to the Northeast (semi-arid) and in the West lies the Great Indian Desert 'Thar'. High wind velocity, huge dune, semi-stabilized and stabilized dunes of different nature, high diurnal variation in temperature, scanty and poor rainfall, intense solar radiation, and high rate of evaporation are the main characteristics of the Thar Desert. The natural grasslands lie in Desert areas are highly deteriorated stage with the productivity of only 300–400 kg/ha/year. *Dichanthium-Cenchrus-Lasiurus* type grasslands are associated with sub-tropical, arid, and semi-arid regions comprising the northern portion of Gujarat and the whole of Rajasthan excluding the Aravalli

ranges in the South, western Uttar Pradesh, Punjab, Haryana, and Delhi State between 23 and 32°N and 68 and 80°E. The principal perennial grass species of such grasslands are buffel-grass (*Cenchrus ciliaris*), birdwood grass (*Cenchrus setigerus*), marvel grass (*Dichanthium annulatum*), khavi grass (*Cymbopogon jawarancusa*), bermuda grass (*Cynodon dactylon*), wire grass (*Eleusine compressa*), sewan grass (*Lasiurus scindicus*), pan dropseed (*Sporobolus marginatus*), *tantia* (*Dactyloctenium sindicum*), halfa grass (*Desmostachya bipinnata*) etc. [1]. The dominant perennial grass *i.e.* indigenous sewan grass is popularly known as the "King of Desert grasses". Sewan grass (*Lasiurus scindicus* Henr.) belongs to the family *Poaceae* is native to dry areas of North Africa, Sudanese and Sahelian regions, East Africa and Asia. It is highly tolerant to drought but should be protected from the wind in the early stages of the establishment [2].

Sewan grass is a bushy, hairy inflorescence, multi-branched, C_4 desert grass and a stout woody rhizome [2, 3] find in wastelands of arid region. The wild form of Sewan grass (*Lasiurus hirsutus*) is a diploid species having somatic chromosome number (2x) 20 however some species of grass are vary with chromosome numbers and polyploidy nature also [4]. Sewan grass is a perennial grass that can live up to 20 years. Fertilization is not necessary because it can be grown through vegetative propagating material such as root slips. Sewan grass forms bushy thickets in sandy deserts where it is used for pasture, hay, and fodder for livestock. It is found in dry open plains, rocky ground, and gravelly soils [5]. It is relished by ruminants but does not stand heavy grazing and disappears when overgrazed [6].

Comparative performance of major grasses (sewan grass, marvel grass, buffel grass, birdwood grass and bermuda grass) of arid region are presented in **Table 1**. Sewan grass has a higher calcium content and lignin than other grasses, such as marvel grass, buffel grass, birdwood grass and bermuda grass. The components of crude fiber are cellulose, lignin and hemicellulose. However, in case of other nutritional properties sewan grass has lower than other grasses but due to its drought resistance ability can grown in very low rainfall condition (lower than 250 mm) and useful for small ruminants such as sheep and goat.

Nutritional quality	Sewan grass	Marvel grass	Buffel grass	Birdwood grass	Bermuda grass
Dry matter (%)	30–33	31–33	28–30	30–32	29–31
Crude protein (%)	6–7	5–6	6.5–7.0	6–7	9–10
Crude fibre (%)	35–55	35–45	38–42	39–40	29–31
NDF (%)	75–77	76.1	75.1	74.0	66.7
ADF (%)	45–49	47.6	46.6	45.0	36.7
Hemicellulose (%)	30–32	28.5	28.5	29.0	30.0
Lignin (%)	7.3	7.1	6.0	6.6	4.7
Ash content (%)	8–9	9.6	9.1	11.0	9.5
Potassium (g/kg DM)	9.5	11.2	19.5	19.0	15.0
Calcium (g/kg DM)	5.1	3.4	2.6	3.8	4.5
Magnesium (g/kg DM)	1.0–2.5	1.1	2.2	2.5	1.8
Phosphorous (g/kg DM)	0.2–1.6	1.6	1.7	1.9	2.2
Organic matter digestibility	52–55	55.1	56.7	57.0	58.4
Energy digestibility	50–52	52.7	54.2	54.9	55.8

Table 1.
Nutritional quality of sewan grass with other major grasses of arid environment.

Thirty days cutting interval at a height of 15 cm gives the best fresh fodder and dry matter yields. Sewan grass yields 2.7 to 10.5 tonnes fresh forage/ha/year and up to 3.4 tonnes DM/ha in well-established swards [3]. The low yield can be improved by annual seeding of companion legumes such as guar bean (*Cyamopsis tetrangonoloba*) or moth bean (*Vigna aconitifolia*) [7, 8]. Sewan grass is very important in arid environments because it covers soil especially at the top 15 to 30 cm that helps to protect soil transportation or soil erosion [9], and improve soil health due to the continued decaying of roots of the grass. It can be used to stabilize desert dunes and hummocks [2, 3]. In deteriorated rangelands of Saudi Arabia, sewan grass helps to control the low value invasive species *Rhazya stricta* by smothering its seedlings. It is a useful tool to improve rangeland management [10]. However, sewan grass tolerates prolonged droughts, but has not been found growing in higher rainfall zones and faces a serious threat of becoming an endangered species due to changes in the land use pattern and overgrazing [11]. Reseeding arid rangelands with species such as *Lasiurus scindicus* were found more palatable than its native species *Lasiurus hirsutus* and improved the forage resources at degraded Dera Ghazi Khan Rangeland in Pakistan [12]. Sewan grass is a palatable grass for goat, sheep, and camel, but supplementation is required to meet their nutritional requirements [13–15]. Supplementation with crushed guar seeds (*Cyamopsis tetragonoloba*) at 150 g/head increased DM intake and diet digestibility in ewes grazing sewan grass [16]. The studies with different vegetations growing on the wastelands and grazing lands showed that the association of sewan with other vegetations depends on the area and rainfall pattern of the zone. In the Jaisalmer district, its association has been seen with *Elusine compressa* whereas, in Bikaner, it also comes well with *Cymbopogon jwarancusa*. Over the years, people of the desert have evolved a lifestyle around the sewan grass, based on animal care.

2. Distribution

In the world, sewan grasslands are mostly found in dryland areas such as African countries, arid and semi-arid regions of Asia, South America and Europe. Sewan grass is mainly grazed by ruminants, generally in association with *Cenchrus ciliaris* and *Cenchrus setigerus*, which occupy the same agro-ecological niche, especially in Rajasthan and Pakistan [12, 17, 18]. In India, sewan grass covers approximately 0.1 million hectares of the area including western Rajasthan, Uttar Pradesh, Haryana, Punjab, some parts of Delhi, and Gujarat [1]. The sewan is the most suitable and occurring species in 18–28 sub-zones of the western Rajasthan. In the western Rajasthan state of India, The main distribution zone starts from the west of Jodhpur to Barmer districts towards Bikaner. The hummocky sandy, plains of Bikaner and Barmer or adjoining districts also support the extensive sewan grasslands. Until the last decade, about 80% of the total geographical area of Jaisalmer district covering Nachana, West Puggal, Mohangarh, Sultana, and Binjewala supported sewan grasslands. The Sriganganagar, and Hanumangarh districts are suitable for Agri-silvi-pasture system with special preference to the sewan as a component.

3. Climatic conditions in Sewan Grasslands

3.1 Rainfall

The high inter annual variation of rainfall is the single major factor influencing the agricultural production in the region. The mean annual rainfall in western

Rajasthan received from 100 to 400 mm in the arid region of Rajasthan with a coefficient of variation of 40–70 per cent. More than 90 per cent of total rainfall is received in rainy season. In these parts, perennial grasses play major role in the economy of rural masses as well as survival of large cattle population. The areas receiving annual rainfall from 100 to 300 mm/year are the main locations where the natural sewan grass exists. The rainfed cropping zone is the main growing zone (More than 80 per cent) of sewan on the interdunal plains.

3.2 Temperature

The desert stands for extremes of temperature ranging from −5.7°C during winters to 48°C during summers. During winters mean maximum temperature varies from 24–26°C parts with the highest mean temperature of 33.3°C in western part of the region. January is the coldest month mean minimum temperature of 6.5 to 9.5°C. During summers, the mean maximum temperature varies from 36.1°C in east to 38°C in the west.

3.3 Drought

The frequency and occurrence of droughts in arid region are much higher than other regions in drought affected states in India. Out of 13 states repeatedly declared as drought-prone, Rajasthan is the most critical state in the country with highest probabilities of drought occurrence and rainfall deficiencies. Several records shows that about 48 drought years have been reported of varied intensity since 1901 in last 102 years and only 9 years out of them were totally free from drought [19]. The impact of recurrent droughts is the less hazardous than the consecutive droughts of 3–4 years (1984–1987). Consecutive droughts affect the sewan fresh fodder production very badly leading to mortality of animals. The studies conducted at CAZRI, Jodhpur revealed that the sewan could survive under extreme arid and severe drought conditions below 250 mm annual rainfall [20]. It has also been observed that the probability of experiencing severe droughts affecting the grass production in a rainfall zone below 200 mm is about 50 per cent. Sewan being a promising desert grass provides sustained forage production for a longer period even under the harsh climate or lean period of arid regions of western Rajasthan.

3.4 Landforms

Sewan has been found to be more suitable for wind strip cropping as an associate component of silvi-pasture system in the areas of sand dunes and undulations of sandy undulating aggraded alluvial, interdunal plains and sandy undulating buried piedmonts. Fourteen major landforms have been identified in Rajasthan as a whole. Among them, mainly the deposited sandy undulating plains are found to be more appropriate for sewan grass coverage and growth.

3.5 Existing situation

A large area as wastelands is available in arid region, which can be utilized for development of grasslands and establishment of pastures. The estimates showed that in India available wastelands vary from 56.60 million ha (17.21 per cent of geographical area of the country i.e. 328.72 Mha). The technologies for improvement and management of pastures, grass-legume mixed pastures and silvipastoral system to increase the carrying capacity of grazing lands is available [21].

3.6 Production technology

The production technologies of sewan grass are different from other arable crops grown under rainfed condition of western Rajasthan because of perennial nature (up to 15 to 20 years after sowing). The grass takes 2–3 years of its development to attain optimum yield and continued for 15 years or more. Generally, the non-cultivable wastelands used for production of sewan grass, which fall under class VIII of Land Use Capability Classification. Packages and practices to be use for production of sewan grass are described in **Table 5**. To mitigate the effect of drought and moisture scarcity adoption of soil-moisture conservation measures are very crucial tools that are presented in **Table 2**.

3.7 Seed production technology

The quality seed production of grasses is a challenging task for the breeders and agronomist. The major constraint in development of pasture is supply of inadequate, poor quality seed. In our country, the requirement of tropical range grasses and legumes is about 3000 t/year whereas the supply is only about 450 t/year having a very large gap between demand and supply. Many problems are associated with the grass seed production. Very low effort has been made to develop the high yielding grass varieties. It has also been noticed that the high fodder yielding varieties are very poor seed yielder. The maintenance of seed purity is also difficult due to its perennial nature and tussock making habit. The seed maturity in sewan grass is unsynchronized. The seed production is vulnerable to adverse weather conditions i.e. windstorms, rainfall, drought etc. It has been noticed that the high wind velocity leads to the mature seeds to fall on the ground and occasional heavy rainfall destroy the seeds. The occurrence of drought or moisture scarcity results in lower seed production. Under these circumstances, seed production opportunity and its exploration are very poor, which restricts popularization of sewan seed production among the farmers. Due to the unsynchronized maturity, it takes seven to ten days for all the spikelet to mature in normal season and it may extend up to 20 days in cooler months [31]. As per Indian Minimum Seed Certification Standards

Measures	Remarks	References
Construction of contour furrows	60 cm wide x 25 cm deep and distance of 10–15 m across the slope. Increases the fodder production up to 130 per cent.	[30]
Inter row water harvesting (IRWH) system	30 cm wide raised ditches are alternated with 70 cm of wide raised bed improves the soil moisture status in the field. Seeds sown on the edge of the ditches increased forage to 66 per cent over conventional system of planting.	[30]
Intercultural operations after 20–30 days of sowing	The most effective and common practice in the field. This practice removes weeds, reduces the loss of water through weeds and the fine particles dispersed on the soil surface by intercultural operation work as a surface dust mulching check the water loss from the soil. The intercultural operation breaks the capillaries and stop water evaporation from the soil which ultimately becomes available to the plants for longer period to the grass.	[30]

Table 2.
Soil-Moisture conservation measures.

Field standards	IMSCS	
	Foundation seed (FS)	Certified seed (CS)
Field standards		
Isolation distance (m)	20	10
Field inspection (nos.)	3	3
Off-type plants (%)	0.10	1.0
Inseparable other crop plants (nos.)	None	None
Objectionable weed plants (nos.)	None	None
Designated diseases (nos.)	None	None
Designated pests (nos.)	None	None
Seed standards		
Minimum Physical purity (%)	80.0	80.0
Minimum Genetic purity (%)	99.0	98.0
Maximum Inert matter (%)	20.0	20.0
Maximum other crop seed (nos./kg)	20	40
Maximum Other varieties seed (nos./kg)	20	10
Fields of the same variety not conforming to varietal purity requirements for certification (nos./kg)	20	20
Fields of another *Lasiurus* spp. known to cross or suspected of being able to cross (nos./kg)	200	200
Maximum Total weed seed (nos./kg)	20	40
Maximum Objectionable weed plants (nos./kg)	None	None
Submitted sample size (gm)	200.0	200.0
Working sample size (gm)	20.0	20.0
Maximum Moisture per cent	12.0	12.0
Minimum Germination per cent	20.0	20.0
For vapour-proof containers per cent	8.0	8.0

Table 3.
*Field and Seed standards for Sewan grass (*Lasiurus scindicus*) as per IMSCS.*

(IMSCS), Field and seed standards for identification, release sewan grass cultivars are mentioned in **Table 3**.

3.8 Seed collection

Different methods have been applied to collect sewan grass seed with less effort:

a. Cutting or collection when upper 25 per cent spike has been matured whole spike with its stem or when 75 per cent of the spike are matured and dried up to 2–3 days then the seeds were collected from spikes. The seed harvest of these methods has 35–40% germination, which satisfactory.

b. Another method introduced by CAZRI, Jodhpur in which caryopses of the spikes harvested by following hand cutting spike heads at optimum time termed as modified method. Seeds were also collected manually as per

maturity called traditional method. The results revealed that mean seed germination percentage of October and November harvests was at par in both the methods while in March harvest this was almost double to the traditional method. However, germination was more in the seed harvest of traditional method. Hence modified method is less labor intensive and cost effective [22].

c. In the forest areas, seed is collected manually from the ground, these seeds have very poor germination percentage due to damage caused by ants. Hand collection as per maturity seed provides quality seed of good germination.

4. Agronomical principles for sewan grass seed production

The site should have all the agro eco-characteristics, which can help in growth, development and management of grass stand. If drought occurs at the time of seed formation, there should be provision of life saving irrigation for quality seed production. The sowing methods, fertilizer application etc. have to be followed as per the practices recommended for grass production (**Table 4**). Under irrigated condition good quality seed could be produced except under low temperature conditions in December and January. Grass should be harvested in the active rainy season to avoid the losses to seed due to rains. If cuts have been taken in July–August, from September onward there will be profuse tillering and more inflorescence production.

5. Sewan in alternate land use system

Alternate land use system is appropriate in areas where subsistence farming is practiced in fragile ecosystems and it poses more potentiality and flexibility in land use than the traditional crop production systems. An ideal system for dry land areas should have a judicious mix of crops, trees and grasses only then the natural resources will be judiciously utilized and returns maximized without any detrimental effect to environment [43]. Different alternate land use systems have classified in arid environments *viz.* Horti-Pasture system, Silvi-Pasture system, Agro-Forestry system, Agri-Pasture system, Agri-Horticultural system, Horti-Silvipasture and Agri-silviculture. Out of them, Agri-Pastoral system, Horti-Pastoral system and Silvi-Pastoral system are found very effective systems in which sewan grass use as alternate crop or grass to give maximum benefits (**Table 5**).

6. Land diversification and value addition

As we have already discussed that sewan grass lives more than 20–25 yielded up to 10–15 years but due to modernization in agriculture i.e. heavy grazing, mechanization, and economically important crop dependency of farmers sewan grass is being disappeared from the farmer's field and limited at wasteland areas. Therefore, there is need to conserved sewan grass and continuously supply sewan forage to the livestock. That can possible through land diversification that means to use land efficiently by growing sewan grass with arable crops without affecting the yield of both grass and arable crops. Strip cropping of sewan grass with arid legumes helps to conserved and maintains yields of both crop and grass. Another way to utilize the non-cultivable forest areas the planting sewan by adopting advanced production technologies and soil moisture measures. Thus, sewan can be used in diversification

Package & Practices	Description
Environmental features	
Soil	Sewan grass performs well on alluvial sandy plains, low dunes, hummocks and light textured soils with pH 8.5. In this type of soil, upper horizon is calcareous but quantity of $CaCO_3$ increases with down profile.
Climate	The climate of sewan-dominated zone has low and erratic rainfall (below 250 mm) and high temperatures. The aridity index is 250 whereas the Thornthwaite moisture Index value is below −40 for sewan grass growing areas. During summer season, temperature should be up to 45°C and in winter season below −3°C.
Agronomic practices	
Land preparation	At the initial stage of growth of grass requires ploughing is essential to make field free from weeds. The land should be properly ploughed once by disc followed by harrow to avoid the termite infestation and favors better establishment of sewan seedlings. To protect the pastures from illicit grazing should be fenced properly that called in local language *Jharberi* or *bordi*.
Varieties	Mostly landraces are dominated in the pasturelands and forest areas of western Rajasthan, Central Arid Zone Research Institute (CAZRI), Jodhpur and its research centers have taken a lead to developed sewan grass varieties. Varieties *viz.* CAZRI Sewan-1 (CAZRI 30–5), Jaisalmeri Sewan (RLSB 11–50), CAZRI 317 and CAZRI 319 have been released in last two decades (2000–2020).
Seed Treatment	To obtain better germination and save the seed from the attack of pests, seeds should be in fresh water for 3 hours and then wash with tap water for about 15 minutes [32]. The insecticide such as BHC or Aldrin powder can be mixed with the mixture to protect the seed from insects after sowing [33]. Seed germination or seed setting can increase foliar spray of combination of Cycocel (100 ppm) and Pactobutrazol (200 ppm) [34]. It has been confirmed that treatment with 0.2% KNO_3 gave significantly higher germination (20.9%) than control (18.0%).
Sowing	Test weight of sewan grass is 7 g, which make as the seeds vulnerable to winds. Therefore, care should be taken for better placement of seed. Generally, two methods are recommended for sowing:-
a) Furrow sowing	In this method, seeds mix with moist sandy soil in 1:5 ratios in such a way that in one crunch of mixer approximately 10–12 seeds should be available for sowing. Furrows opened with the help of tractor or desi plough and drilled the mixtures in 2-3 cm depth with 75 to 100 cm spacing then covered with soil layer to avoid the instant loss of soil moisture from furrows and safety the seed from ants and other biotic agents [35, 36]. The intercropping of *L. scindicus* and *C. ciliaris* give higher yield than their sole cropping. This system will be better for development and renovation of pastures and rangelands.
b) Pellets sowing	This method can be adopted for dry sowing as well as wet sowing to prevent loss of grass seed on windy days and from birds and ants. The pallets made by mixing in a particular proportion of 100-125 g seed: 3500 g clay: 250 g FYM: 250 g sand with a desired quantity of water and dried in shade for 24 hours with hand *chazlla or* a simple rotary pellet-making device developed by CAZRI, jodhpur [37]. Suitable size of pellets should be 0.5 cm contains 2–3 seeds.

Package & Practices	Description
Sowing time, Seed rate and Spacing	Suitable sowing time as dry sowing is before the onset of monsoon under wet condition after the rains. The optimum seed rate is very important for getting the desired plant population in the field otherwise, growth of clumps at later stages are badly affected with heavy competition for moisture and nutrient as well as the space. 3–4 kg/ha seeds will be sufficient for one hectare area [35] and recommended crop geometry for sewan grass is 75–100 cm x 50–75 cm.
Fertilizer management	Desert soil has many advantages (better water releasing capacity) and disadvantages (poor water holding capacity) in terms of rainfed cropping of grasses as well as crops. Nitrogen, Phosphorus and Potassium uptake significantly higher in half-yearly cuttings than annual cuttings. Before sowing FYM or other compost including sheep and goat manures should be added approximately 5–7 t/ha and the recommended basal application is 30 kg nitrogen (two split doses) +40 kg P_20_5 /ha has been found effective and economical dose for better establishment and higher forage yield [38]. The side placement has been found better than the broadcasting method of fertilizer application in the sandy soils.
Use of Bio regulators	Foliar spray of Thiourea (0.05%) and GA_3 (10 ppm) have positive significant effect on the seed yield of sewan grass. It induces the translocation of nutrient another part and many metabolic activities.
Irrigation management	Sewan is generally managed in natural rangelands in rainfed condition and major growing period is monsoon season. It is believed that if sewan is irrigated the productivity of grass will decrease and its life span will decrease form 10 years to 5 years. However, the experiment conducted at CAZRI, Jodhpur has shown that light irrigation through sprinklers with supplementation of nitrogen has increased yields (green forage yield 25.1 tones/ha and dry forage yield of 8.8 tones/ha) over the years [39]. It has been earlier reported that *L. scindicus* showed maximum water and energy use efficiency as compared to *C. ciliaris* and *C. setigerus*.
Irrigation scheduling	1. I cut at the end of August (rainfed), 2. I and II irrigations of 100 mm in October and November through sprinkler irrigation system with a cutting at the end of each month, 3. III irrigation of 100 mm at mid February and cutting at the end of March, and 4. IV irrigation of 100 mm at the end of March and cutting at the end of June.
Forage production	The highest green forage and dry matter yields recorded 88.57, 29.08 and 95.38, 30.19 q/ha from I and II cutting was recorded at 40 kg N/ha when applied full dose in July, respectively [38, 40].
Weed management	Weeds compete with the grass seedlings especially at the initial stages of its growth and development. Therefore, for efficient use of available soil moisture and nutrient by grasses the eradication of weeds is very important at the initial stage. It has been observed that although hand weeding is expensive but more effective than the chemical weeding. The grasses have fodder value hence chemical weeding is not advised. It has been proved that two weeding by hand hoe and after 20 days have been found effective and remunerative.

Package & Practices	Description
Harvesting	The sewan grass is ready to harvest after about 35 to 40 days after the effective rains. The nutritive status of fodder at maturity stage is lowest but total dry matter is more. Therefore, nutritive value of fodder yields should be harvested at green stage after the flowering. The harvesting can be done using mechanical harvester and grass cubes can be made for its unchaffed storage. In general, the grass is harvested by sickle and after drying, it is chaffed by the chaffing machine.
Ageing and productivity	Due to perennial nature, increase in age of the clumps increase green forage yield (15–17 q/ha) [41].
Soil Fertility	An experiment conducted at CSWRI, Bikaner from 2001 to 2003 revealed that the cultivation of sewan has non-significant effect on the soil EC and pH but soil organic carbon increase gradually. Available nitrogen, phosphorus and potassium significantly increased in the soil after three years [42].
Yield	From a well-managed sewan grass with good plant population 20–25 kg/ha seed and 35–40 q/ha dry forage can be produced. The yield potential is quite high *i.e.* about 250 kg/ha/year.

Table 4.
Environmental features and Agronomic practices for sewan grass production.

Alternate land use system	Remarks	References
Horti-Pastural system	Earlier study on this system has been revealed that sewan grass growth not affected with Horticultural intercrop (*Ziziphus mauritiana*)	[22]
Silvi-Pastural system	It has reported that in wastelands areas of arid regions, sewan grass intercropped with forest trees (*Acacia nilotica*, *Acacia tortilis*, *Acacia senegal* and *Colophospermum mopane*) and observed that sewan grass utilized moisture below 2 m soil surface whereas the trees takes the moisture more than 2 m depth. Thus, the system ensures best utilization of rainfall water and maintains temperature for biomass production. Some of the Silvi-Pastural systems with sewan grass are sewan + *C. mopane*, sewan + khejri, sewan + khejri + *C. mopane*, Sewan + *A. tortilis*, Sewan + *Acacia nilotica*, sewan + *Acacia senega*, sewan + *Ziziphus mauritiana*, *C. mopane* + *L. sindicus* + cowpea, *L. sindicus* + cowpea + *C. mopane* + *H. binnata*	[22–24]
Agri-Pastoral system		
Mixed cropping	Old practice among the farmers of western Rajasthan. This grass mixed with legumes increase fresh forage and dry matter yields. Example: *L. sindicus* + *C. ciliaris, L. sindicus* + *C. ciliaris* + *C. setigerus, L. sindicus* + *D. lablab*	[25, 26]
Intercropping	Intercropping of arid legumes (mungbean, moth and guar) with perennial grass include sewan, buffel grass and birdwood grass help to increase yields and stabilizes the economy of arid zone farmers.	[27]
Strip cropping system	Two crops of different growth habit are grown in a specified width of strips for enhancing the land productivity and reducing the soil erosion. Examples: Sewan + Mothbean (1:4), Sewan + Guar (1:4)	[28, 29]

Table 5.
Alternate land use system with Lasiurus sindicus.

and resource conservation in arid tract of Rajasthan. Sewan grass can be used as hay and silage during lean period when fodder is not available for livestock. The silage is a good quality fodder and can be fed to the animals during the off-season. An experiment conduced at CAZRI, Jodhpur and results revealed that quality silage of sewan fodder can be increased by adding 1–2% urea, 10% juggary and 4% starter culture (*Lactobacillus* culture) [41]. Sewan grass hay can be utilized as an excellent feed for dairy cattle that can be prepared by harvest at the proper physiological stage of growth and well cured to 20 per cent or less moisture.

An experiment conduced at CSWRI, Bikaner and results revealed that dry matter consumption through sewan hay was found to be higher than *C. ciliaris* hay where as digestibility of dry matter was lower in sewan hay than *C. ciliaris* [42].

7. Breeding efforts and achievements

Plant breeding deals with principles and procedures to improve the genetic constitution of crop species based on two basic principles such as creation of variation and selection. Naturally occurring variations in sewan grass already exist due to its cross-pollinated nature. Diversity existing among the germplasm help to select the diverse parents that help to introgression or combine the trait of interest into the elite cultivar [44] which can be estimated by clustering approaches such as Metroglyph analysis [45], D^2 statistics [46], Principal Component Analysis (PCA) [47] and molecular markers. Sewan grass is used for fodder purposes so that forage yield is the economically important complex or super trait. Direct selection for yields *per se* cannot be very effective. The study of inter-relationships is necessary for understanding the association of component traits with complex characters. Generally positive association between yield and component traits is beneficence for crop except maturity and anthesis traits in arid region otherwise it is advisable to break linkage drag between traits which made be possible through various population improvement strategies i.e. recurrent selection and its modifications, Disruptive selection mating and Marker-assisted recurrent selection, genomic selection, Genome editing methods etc. Now a day, in sewan grass, recurrent selection method and its modifications are being popularized for population improvement and varietal development. A lot of effort is still required to move applications for plant breeding beyond the experimental scale in sewan grass; however, Yadav and Krishna [48]; Shekhawat et al. [49]; Sanadya et al. [44, 50, 51]; have been screened large number of accessions of sewan grass for yield and its component traits and revealed that tillers number and dry matter yield are those characters showing high amount of variation and green fodder yield showed strong positively significant correlation with spike length, tillers number and dry matter yield. Sanadya et al. [50] have classified large number of sewan grass accessions into seven clusters using the Metroglyph method and Sharma et al. [11] grouped sewan grass accessions into five clusters using RAPD and ISSR markers. Chowdhury et al. [52, 53] found *nifH* gene in the rhizospheric region of sewan grass and also studied on diversity of 16sRNA and reported that sewan grass roots have been affiliated with a few of the nitrogen fixation bacteria *i.e. Pseudomonas pseudoalcaligenes*, *Azospirillum brasilense*, *Rhizobium* sp., and uncultured bacteria.

8. Conclusion

Arid zones are known to be fragile ecosystems in which various grasses have been introduced that tolerate high temperatures and low rainfall (below 250 mm)

such as buffel-grass (*Cenchrus ciliaris*), birdwood grass (*Cenchrus setigerus*), marvel grass (*Dichanthium annulatum*), khavi grass (*Cymbopogon jawarancusa*), bermuda grass (*Cynodon dactylon*), wire grass (*Eleusine compressa*), sewan grass (*Lasiurus scindicus*), pan dropseed (*Sporobolus marginatus*), *tantia* (*Dactyloctenium sindicum*), halfa grass (*Desmostachya bipinnata*) etc. among them sewan grass is more popular because of good nutritive value and soil binder properties. This grass can be intercropped with other grasses, arid-legumes and desert trees with numerous alternate land use systems such as Agri-Pastoral system, Horti-Pastoral system, Silvi-Pastoral system and Agroforestry to complete, ecologically sustainable livelihood system. Although salt tolerance, drought tolerance, soil binder, nitrogen fixation, alternate land use system, ecofriendly nature, good palatilibity and high digestibility for livestock still plant breeders are not showing interest to popularize it to be farmers.

There are many reasons behind low popularization of sewan grass on farmer's field such as sewan grass found in extreme areas (high temperature), modernization in agriculture, cultivation of economically important crops, researches limited to agronomic perspective, limited R & D, seeds are very low weight and environmental conditions are highly variable (sandstroms), poor education and awareness, overgrazing, low profitable than economic important crops, uneven pod setting, non-synchronous maturation, present land utilization does not permit any more good land to be put for fodder production, and no governmental policies for conservation of sewan grass germplasm. Therefore, to meet both present and future demands, policies need to be supportive of the development of these traditional Agroforestry systems. Sewan grass has numerous qualities such as lodging resistance, drought tolerance, C_4 grass, associated with beneficial bacterial colonies but still facing negligence from scientist communities. Therefore, these traits can be utilized for germplasm enhancement and it is mentioned earlier that intercropping of sewan with other crops and trees or shrubs also help to prevent soil erosion and maintain soil fertility. There is needed to be popularized fodder of sewan grass to the farmers so that can conserve sewan grass germplasm and generate extra income for their livelihood. If improvements could be made in forage quality, especially more high yield varieties with good nutrition, then potentially huge improvements in the animal production can be made. In conclusion, utilizing the information obtained from the research effort to improve grain crops and the knowledge gathered from model systems like *Brachypodium* and setaria, offers an excellent future perspective for improving the nutritional quality and yield for forage crops. The sustainable or ecological intensification of grass-based food production systems provides an opportunity to align the ever increasing global demand for food with the necessity to re-green ruminant production. Still integration of traditional breeding with modern approaches are missing in sewan grass therefore, modern genetics should be quickly integrated into the current conservation, use and improvement strategies to address nutritional quality and palatability concerns, in sewan grass.

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